



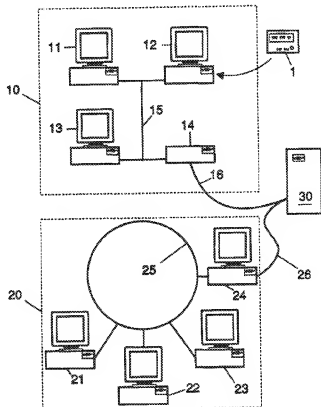
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(54) Title: METHOD AND APPARATUS FOR SECURE IDENTIFICATION OF A MOBILE USER IN A COMMUNICATION NETWORK

## (57) Abstract

Communication between mobile users of and in a computer network is subject to a variety of security issues; user identification and user tracking are two particularly important ones. This invention provides a method and an apparatus for securely identifying a mobile user while avoiding trackability of his/her movements, i.e. it provides a way for a secure user identification in secrecy. The gist is to encrypt the user's identifier, and/or his/her password, and a synchronization indication, preferably a fixed time interval, under a secret one-way function and sending the encrypted message, herein called "dynamic user identifier", to the user's "home authority" where he/she is registered. The home authority comprises correspondence tables listing, pre-computed for every time interval (or another chosen synchronization), the dynamic user identifiers and the corresponding true identity of the user and can thus quickly decide whether the received encrypted message originates from a registered user. On the other hand, an intruder is neither able to detect from the encrypted messages the identity of the user nor can he/she track a user's moves.



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**DESCRIPTION**

Method and apparatus for secure identification of a mobile user in a communication network

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**Technical Field**

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This invention relates to communication between mobile users of and in a computer network; more specifically, it concerns a method and an apparatus for establishing a way of providing secure identification of a mobile user in a communication network.

15

**Background of the Invention**

- In today's communication networks, user mobility is rapidly becoming an important and popular feature, particularly in wireless or cellular networks. While useful and desirable, this increased user mobility leads to a number of important security-related issues and concerns. One issue is the approval or acceptance of the user; another issue is the tracking a mobile user's movements and current whereabouts.
- A typical situation arising in mobile environments is when an entity, i.e. a user or a device, registered in a particular home domain, appears in a different, i.e. foreign domain. Presumably, this user's goal is to obtain certain services while in the foreign domain. Since this user is not known in the foreign domain, he/she must be authenticated and his/her "solvency" or good standing must be confirmed to the authority of the foreign domain. Within the following specification, this process is denominated "authentication", as usual in the art. Of course, the only entity able to comment on the user's identity and current standing is the authority in

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- 1 his/her home domain. There are several known solutions to this problem in  
the recent literature, some of them are addressed below. However,  
authentication is not the issue that the present invention addresses.
- 5 Of concern here is another security-related issue arising as a result of user  
mobility. It is the confidentiality of the user's identity and his/her  
movements. Ideally, only the user's home domain authority should be  
informed as to the mobile user's itinerary and current whereabouts. In the  
following, this process of establishing the identity of a mobile user, i.e. of  
10 determining WHO the user is trying to obtain a service from a particular  
domain actually, is denominated "identification".

15 Ideally, no entity other than the user himself/herself and a responsible  
authority in the user's home domain, i.e. the subnetwork or partition of the  
network within which the user typically works, should know the real identity  
and/or the current location of the mobile user. Current environments  
supporting user mobility either do not address the problem at all or base  
their solutions on hardware capabilities of the user's personal device.

- 20 Generally, one may say that the known solutions for this problem offered by  
current state-of-the-art mobile/cellular architectures are either inadequate or  
too specific to assure a secure identification in secrecy, as detailed below.

One of the presently available solutions is reported by M. Rahnema in (1). In  
25 this so-called GSM system, the mobile user is routinely assigned a  
temporary identity (TMSI, in GSM parlance) when he/she appears in a  
foreign domain. However, a TMSI is only assigned after the initial  
authentication of the mobile user in the foreign domain; in the process  
carried out by the latter, the user's real identity (IMSI, in GSM parlance) is  
30 communicated in the clear and can thus be recognized and misused by an  
intruder.

1 Another solution is described in a specification (2) on a "Cellular Digital  
Packet Data" (CDPD) system. The approach taken by the CDPD system is  
more secure than in the above GSM solution. In the CDPD system, before a  
mobile user communicates his/her identity, he/she engages in a  
5 Diffie-Hellman key exchange protocol with the local, i.e. foreign, domain  
authority. This protocol is described by W. Diffie and M. Hellman in (3). As a  
result, both parties come to share a secret key. Enciphered under this key,  
the mobile user subsequently transmits his/her identity to the foreign  
domain authority.

10 While more secure than GSM, this approach has two major drawbacks. First,  
it allows the local, i.e. foreign, domain authority to discover the real identity  
of the mobile user. In the context of CDPD, this is not a problem in and of  
itself. However, ideally, the identity of the mobile user should not be  
15 revealed to the local domain authority. It is sufficient for establishing his/her  
identity and current standing if it is corroborated or endorsed by the home  
domain authority. The second problem is due to the nature of the  
Diffie-Hellman key exchange protocol. Its purpose is to establish a secret  
key on-the-fly. This allows an intruder to masquerade as the local domain  
20 authority and thus to engage in the key exchange protocol with the mobile  
user and obtain a shared key. When the mobile user then transmits its real  
identity enciphered with this same key, an intruder will simply decipher the  
transmission.

25 Other approaches are given by R. Molva et al in (4) and by M. Beller et al in  
(5). One side aspect, relating to key distribution, is described in Applicant's  
PCT Application PCT/EP93/01989 (6), another side aspect, relating to  
password or key change, is addressed in Applicant's PCT Application  
PCT/EP93/02540 (7).

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In summary, there are essentially three issues underlying the problem of  
mobile user identity and movement confidentiality.

1 The central issue in maintaining a secret identity is to prevent anyone from  
discovering a correspondence between a mobile user and a user registered  
in a particular home domain, in other words, the central issue is to keep the  
user's identity confidential. The easiest, rather intuitive solution is to assign  
5 a travelling alias to every mobile user or device when away from the home  
domain. As addressed below, this alias can be fixed or ever-changing.  
Consequently, a main object of the invention is to devise a method and a  
system that is adapted to and permits the use of such aliases.

10 The second important issue is to keep foreign domains "in the dark". If it is  
not imperative for a foreign domain to know the real user's identity, an alias  
should suffice. In most cases such an alias must still be corroborated by the  
home domain authority. Consequently, another object of the invention is to  
design a method and a system which enables the information flow through  
15 the network without revealing the identity of the user to the foreign domain.  
(Whether or not aliases are used, there may be reasons why the foreign  
domain authority still demands to know the real identity of the user. In this  
case, the home domain authority may communicate the user's identity in  
secret, assuming, of course, that the two authorities have a pre-established  
20 means for secure communication. However, even in this case, the foreign  
domain originally does not know the user's identity.)

The third issue of particular concern is to prevent identity tracking or  
correlation. Even if a mobile user adopts a travelling alias, his/her  
25 movements can still be tracked by a hostile intruder. This is especially  
possible if the alias is fairly static, e.g. fixed for a given trip of a user or  
permanently allocated to said user. An alias of this latter type is similar to a  
long-term password: once cracked, the identity and the movements of the  
user can be compromised on a long-term basis. Consequently, a further  
30 object of the invention is to prevent the tracking by devising a system  
geared and adapted to use frequently changing aliases without inhibiting  
the information flow.

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#### Summary of the Invention

15 The present invention presents a solution to the above described issues. In  
brief, to minimize or avoid traceability and identification of a mobile user, a  
method of assigning temporary, simple, one-time aliases to travelling users  
was devised, which is both efficient and not specific to a particular  
hardware. The invention allows, on one hand, for unambiguous and  
20 practically instantaneous identification of the travelling user by his home  
authority; on the other hand, an unauthorized party is unable to identify the  
mobile user or track his/her movements.

Though the invention addresses and provides a comprehensive solution for  
25 all three aspects discussed above, there are still some limitations that are  
difficult to circumvent. One such limitation, for example, is the need of the  
foreign domain authority to know the identity of the home domain of the  
travelling user. This is likely to be the case for quite a number of  
mobile-user environments, since charges incurred "abroad" must be  
30 eventually propagated to the home domain. Furthermore, as mentioned  
before, only the home domain can comment on the user's current standing.  
(To solve this particular problem, one could envisage a system environment  
where communication between domain authorities is "anonymized" by a



1 central clearinghouse. In this case, it would be beneficial to assign aliases  
to domains so that a travelling user can reference his/her home domain by  
an alias; it then would be up to the central clearinghouse to resolve the  
domain aliases.)

5 The method according to the invention tries to reconcile two seemingly  
conflicting requirements: authentication and identity confidentiality. To  
authenticate an entity, it must first claim a certain identity and subsequently  
show or prove that it knows something that only the actual bearer of that  
10 identity can possibly know. Identity confidentiality, on the other hand,  
demands that the same identity be kept secret. This results in a somewhat  
paradoxical situation which must be solved.

In brief, the essence of the new method is in computing short-term travelling  
15 aliases, hereinafter called "dynamic user identifiers". A user travelling  
outside of his/her home domain can assume such an alias and hide all  
relationship to his real identity. Moreover, this remains to be the case even  
if the foreign domain (or any unauthorized party) manages to discover the  
travelling user's password.

20

### Notations and Brief Description of the Drawings

#### Notations Used

25 The following notation is used throughout this description:

- $D_x$ : domain name;
- $AS_x$ : authority of domain  $D_x$ , typically an authentication server;
- $U$ : travelling user, domiciled in domain  $D_x$ ;
- 30  $U_x$ : (real) name of this travelling user  $U$ ;
- $A_u$ : alias or identifier of this travelling user  $U$
- $PW_u$ : user  $U$ 's password
- $SUId$ : dynamic user identifier

- 1     $\delta_x$ :    time interval of domain x  
      $T_U$ :    time interval indicator, i.e. present time of user U rounded to the  
         nearest  $\delta$  value.

5    In the drawings is depicted in

Fig. 1 — a smartcard, useable for this invention, in both of its modes;

Fig. 2 — an example for the information flow from the smartcard to the  
10    user's home authority:

Fig. 3 — a network with two domains for demonstrating the use of the  
invention;

15    Fig. 4 — an example for the organization of the home authority's process;  
     and

Fig. 5 — an example for the process at the foreign input workstation or  
terminal.

20

### Detailed Description

Initially, every mobile user is assigned a long-term travelling alias  $A_U$  in  
addition to his permanent identity. In principle,  $A_U$  does not have to be  
25    different from the user's real identifier  $U_x$ ; the security of the scheme does  
not depend on  $A_U$  being secret. In an environment where each user is  
equipped with a smartcard or some similar device,  $A_U$  may be nothing more  
than the serial number or any other unique identifier of the user's device. A  
list of these travelling aliases  $A_U$  is maintained by the home domain  
30    authority alongside passwords and other user information.

For every domain  $D_x$ , a domain-wide time interval  $\delta_x$  is selected. This time  
interval  $\delta_x$  can be relatively coarse, for example an hour or a day.

1

When a user U, whose home domain is  $D_x$ , travels to a foreign domain  $D_y$ , he/she first needs to be identified (and authenticated). Subsequently, a temporary record can be created for him/her in  $D_y$  to facilitate subsequent  
5 accesses in this foreign domain. In other words, if the user plans to linger within  $D_y$  for some time, it may be advantageous to establish some temporary "home" for him instead of having to contact the user's home domain upon every access. But this is just one further possibility. The main goal of the invention is the identification of a user.

10

A detailed description of a protocol for authentication of a user can be found in Molva (4) which is herewith incorporated by reference. The exact format of the authentication flows is not important in the context of the present invention. Regardless of the authentication specifics, the identity of user U  
15 must be communicated to his/her home domain authority  $AS_x$ . Since user U cannot directly communicate with the home domain authority  $AS_x$ , all communication has to flow through the local authority  $AS_y$ . This is shown in Fig. 2, described further down.

20

The authentication protocol may be optionally preceded by a two-flow Diffie-Hellman key change as described in the above-cited CDPD System Specification (2). In this case, the entire procedure becomes resistant to passive intruders since all messages can be enciphered using the new key.

25

In general, the identification flow must include the dynamic user identifier *Suid*; this is true both for the (first) flow from the smartcard/user to the foreign authority  $AS_y$  and the (second) flow from  $AS_y$  to the user's home authority  $AS_x$ . The dynamic user identification may consist of *Suid* straightaway or, possibly, an encrypted version of *Suid*.

30

The crucial aspect of the protocol, with respect to the confidentiality of the user's identity, is the computation of the dynamic user identifier *Suid*; it is computed as:

1

$$SUid = F(A_U, T_U, PW_U)$$

wherein  $F$  is a strong one-way function. Examples are DES described in  
Publication 46 of the National Bureau of Standards, cf. (8) above under  
"References", or MD5, disclosed by Rivest in (7). In case of DES or some  
other encryption-based function, it is important to note that no additional  
secret key is necessary to compute the function  $F$  since the user's password  
 $PW_U$  is sufficient for that purpose.  $T_U$  is the current time rounded to the  
nearest  $\delta$  value. If the user is not equipped with a smartcard-like device, he  
enters his/her password  $PW_U$  into the public workstation or other such  
terminal, i.e. the input device connected to the foreign domain authority  
 $AS_Y$ . For a smartcard-bound user,  $PW_U$  can be either: 1. a strong key within  
the smartcard (for those smartcards that lack a keypad or other means of  
input), or 2. a combination of the smartcard's key and the user's password  
(for smartcards with input capabilities).

As specified, the dynamic user identifier value  $SUid$  is unintelligible to the  
foreign domain authority  $AS_Y$ . The only information that the foreign authority  
 $AS_Y$  is able to obtain is that the mobile user registered in the (home)  
domain  $D_X$ . In the second flow, the foreign domain authority  $AS_Y$  transmits  
 $SUid$  (along other, e.g. authentication information) to the user's claimed  
home domain authority  $AS_X$ .

The issue is how the home domain authority  $AS_X$  determines that  $SUid$   
corresponds to the locally registered user  $U$ . It does so by maintaining an  
up-to-date table which, for each native user, lists the corresponding dynamic  
 $SUid$  value. This translation or reference table is re-computed every  $\delta_X$   
interval. Since the home domain authority  $AS_X$  already stores the alias  $A_U$   
and the password  $PW_U$  for every user, it has all the necessary information  
to compute up-to-date translation tables.

30

1 It should be noted that, since the dynamic user identifiers *SUId* do not  
depend on the users' current location, the translation tables can be  
pre-computed off-line and well in advance. This is particularly the case when  
a relatively coarse  $\delta_x$  value is used, e.g. one hour or one day, as mentioned  
5 above.

Of course, establishing the "real" identity of the mobile user is only half the  
work; the home domain authority  $AS_x$  must then verify the authentication  
information supplied in the second flow. However, this is unrelated to the  
10 problem at hand; as mentioned before, Molva et al describe an example in  
(4).

The following section addresses an advantageous arrangement to reduce  
the "computational overhead". In an environment where only few users  
15 travel outside their home domain, it can be quite inefficient and even  
wasteful to pre-compute, maintain, and search time-based alias tables for all  
users. In this case, a way to reduce overhead is to generally require a user  
U to inform his/her home domain authority  $AS_x$  in advance of intended  
travelling. Thus, the home domain authority must keep track of only those  
20 users that are currently travelling. This does not necessarily imply that  
users need to disclose their complete itinerary in advance; they simply need  
to register the beginning of each trip "abroad", i.e. to a foreign domain.  
Upon notification, the home domain authority  $AS_x$  adds the travelling user  
to a special list which is utilized for time-based dynamic identifier  
25 computation. However, it is not necessary for the user to inform his/her  
home domain authority  $AS_x$  upon completion of each trip; the home domain  
authority can deduce that a certain user has returned home when this user  
tries to log in with his/her real, i.e. home user ID at the home domain  
authority.

30

In the following, the clock synchronization between the home domain  
authority and the foreign domain authority is addressed. The assumption  
about the user maintaining a coarse clock, loosely-synchronized with the

- 1 home domain authority is certainly realistic for most environments. Clearly,  
a user equipped with a smartcard can rely on the smartcard's clock to keep  
track of the user time  $T_U$ . For an "unequipped" user, a workstation's internal  
clock will suffice. It is also possible for the user to enter the time manually  
5 from a wall-clock or a wristwatch. Of course, the granularity of  $\delta_X$  is  
decisive. Despite this obvious ease of maintaining the user time  $T_U$ , it is  
conceivable that in some cases, keeping track of  $T_U$  is not possible for some  
reason.
- 10 To handle this situation, the protocol can be modified in a way that either, 1.  
the local (i.e. foreign) domain authority  $AS_Y$  provides the time  $T_U$ , or, 2. the  
user's home domain authority  $AS_X$  provides it. In either case, the time must  
be supplied to the user (or his device) a priori, i.e., in an extra flow  
preceding the first flow as described above. This can be done in the open,  
15 i.e. in clear text, since the time  $T_X$  is not a secret value.

To summarize, as demonstrated above, the most important factor in  
travelling incognito is to have frequently changing and seemingly unrelated  
aliases, i.e. dynamic user identifiers. As soon as constant or long-term  
20 identifiers are used, identity-correlation and tracking becomes possible.  
Ideally, an alias or dynamic identifier is fully disposable, i.e., use only once.  
The method according to the invention is not fully up to that standard  
because it allows aliases to be re-used within the configurable  $\delta_X$  time  
interval. Consequently, if a user migrates through multiple domains within a  
25 single  $\delta_X$  interval, he/she is vulnerable to some limited identity tracking.

To avoid this, the invention offers two alternative approaches:

1. the aliases are made dependent on the visited domain. or
- 30 2. tight synchronization between the user and his/her domain authority is  
maintained.

1 If the name of a foreign domain is included into the computation of a  
dynamic user identifier  $SUId$ , correlation of identity becomes impossible  
since a user migrating from one foreign domain to the next (even within a  
very short time, i.e. within a single time interval  $\delta_X$ ) will do so under  
5 unrelated dynamic user identifiers. The main drawback of this approach is  
that it needs more time. Since, in this case, the home domain authority  $AS_X$   
is unable to predict its user's movements, it cannot pre-compute the  
translation tables. Thus, when the home domain authority  $AS_X$  is presented  
with a dynamic user identifier  $SUId$  and the name of the foreign domain  
10 authority  $D_Y$ , it is unable to resolve or interpret  $SUId$  immediately, and thus  
answer directly, since there is no pre-computed, stored translation table.  
Instead, for every registered user  $U$ , the home domain authority  $AS_X$  has to  
compute the appropriate  $SUId$  value using the name of  $D_Y$  as one of the  
inputs. This puts a substantial load on the home domain authority  $AS_X$ .

15

The other possibility is to maintain tight synchronization between the user  
(or, rather, personal device of the user) and the home domain authority.  
This synchronization can be on the basis of time, secret sequence numbers  
or identically-seeded random number generators. This approach provides  
20 the highest level of security since it guarantees that an alias or dynamic  
user identifier is never reused. It suffers, however, from the same drawback  
as the domain-dependent aliases. Furthermore, it requires every user to  
have a reliable, tamper-proof personal device.

25 The described time-based aliases can be realized in device-oriented  
environments, e.g., smartcards, cellular telephones, or in more traditional  
environments where a travelling user has only a password for  
authentication. In the latter case, a user is unavoidably vulnerable to  
compromised public workstations or other impersonal end-user equipment  
30 which is used to access the network. One preferred example for the  
implementation of the invention is given below.

1 A particular advantageous application of the invention is in connection with smartcards. The simplest possible smartcard is the kind that has only a small display and, perhaps, an on/off switch. Inside its tamper-proof packaging, a smartcard maintains a clock and a secret key unique for each  
5 card. This type of smartcard was described by R. Molva et al in (10). A commercial product that could be adapted to work in this mode is the SecureID token described in (11).

#### Implementation

10

Figs. 1 through 5 show an implementation of the invention with smartcards in graphical form. The following description gives the details.

Smartcard 1, shown in Fig. 1, comprises a serial number 2 which is usually  
15 fixed to the card and unique; it also comprises a processor and a display screen 3, often a small LCD, all battery powered. As explained below, smartcard 1 has two different modes; to support the time-based dynamic user identification method, the following features are provided:

- 20 1. It is programmed to switch either automatically or on demand between two modes, an "authentication mode", wherein the card displays an authenticator (not of concern here, as explained above) and a "user ID mode", wherein the card displays the dynamic user identifier *Suid*. The automatic switching occurs every so often, e.g., every ten seconds. The  
25 automatically switched smartcard is particularly attractive since it does not require any surface or hardware modifications of presently available smartcards. Alternatively, a mode button or switch 4 can be provided that allows the user to switch between the two modes.
- 30 2. The smartcard's clock used in the authentication mode is "coarsened" when computing the user identification *Suid*. A separate clock for the user ID mode is not needed, but could still be provided.



1 In the user ID mode, smartcard 1 displays a 6-8 digit decimal number or  
other sequence of symbols, shown as XX XX XXX in Fig. 1, as the time-based  
dynamic user identifier. This user identifier may include a preceding mark 5  
to indicate that the user identifier is shown. The user duly enters this as his  
5 "user ID" into the terminal or workstation for transmission to the foreign  
domain authority. As mentioned below, this input step can also be carried  
out automatically. It should be clear at this point that the dynamic user  
identifier carries the user identification only in encrypted form; no intruder  
will be able to conclude from it the true identity of the user. It should  
10 further be clear that, since the dynamic user identifier is modified after a  
given time interval, any sequence of dynamic user identifiers is apparently  
unrelated to each other and gives no visible indication of belonging to the  
same user.

15 In the authentication mode, smartcard 1 displays another 6-8 digit decimal  
number or other symbol sequence, shown as YYY YYY YY in Fig.1, as the  
user authenticator. The user enters this authenticator as his "password" into  
the terminal which in turn transmits it to the foreign domain authority. (The  
authentication process itself, as mentioned above, is no part of this  
20 invention and will thus not be described in further detail.)

Such a smartcard could be implemented by modifying a commercially  
available smartcard like the SecurID card referred to in (11) which  
apparently already includes a clock and a processor. For someone skilled in  
25 the art, the writing of the appropriate software - if necessary - and the  
adaptation of the card should not pose a problem. There is not even a  
physical modification of the card necessary if the automatic switching from  
user ID mode to authentication mode is selected.

30 Fig. 2 shows the transmission of the dynamic user identifier and the  
authenticator from smartcard 1 via the foreign domain authority 6 to the  
user's home domain authority 8.

1     One preferable way is that the user inputs both values from smartcard 1, as  
displayed. Another way is to read the card in a terminal connected to the  
foreign authority 6. The usual automatic teller machines as used extensively  
in the banking business could be modified to do that. (Of course, for  
5     authentication, the user may also have to enter a password, PIN number, or  
whatever means is used by the system for the authorization process. Again,  
as mentioned above, the authorization process is no part of this invention;  
any of the conventional methods can be used.)

10    The foreign domain authority 6 "knows" which home domain authority it has  
to address. This is preferably done by including an appropriate section into  
the dynamic user identifier. Alternatively, a separate input can be requested  
from the user by foreign domain authority 6 to identify the user's home  
authority.

15     The foreign domain authority 6 transfers the data via connection 7, indicated  
schematically in Fig. 2 as a cable, to the user's home domain authority. Of  
course, this can be anything from a two-wire connection to a radio or  
infrared communication network. An intruder deriving data from the foreign  
20    domain authority 6 or the connection 7 will not be able to detect the user's  
true identity or his/her previous place of access to the system.

Since the dynamic user identifier *SUId* is already encrypted, a further  
encryption for a more secure transmission is not necessary, but can of  
25    course still be provided.

Fig. 3 shows a network consisting of two domains 10 and 20, each having a  
number of terminals or workstations for user access. The first domain 10  
has a bus 15, connecting its user terminals 11 to 13 and a server 14. A link,  
30    here shown as a line or cable, connects server 14 to a gateway 30. Some or  
all of terminals or workstations have built-in computing power. Also, the  
domain authority may be distributed and not located in a particular machine  
or server.

1

The second domain 20 also has a number of terminals or workstations 21 to 24, here connected to a token ring 25. At least workstation 24 has built-in computing power and is employed as a server for this second domain.  
5 Connection 26, shown as a line, can as well be a wireless infrared or radio connection to gateway 30.

A travelling user U who wants to access the system via terminal or workstation 12, and who is "at home" in domain 20, enters his/her data, i.e.  
10 identifier, password, etc., into a keyboard or other input device at terminal 12 and/or puts his/her smartcard into a reader at the workstation. Since workstation 12 is - from the user's viewpoint - part of a foreign domain, he/she will be asked to enter his/her home domain name or it will be read from the smartcard. Either workstation 12 or, alternatively, the user's  
15 smartcard compute the dynamic user identifier *SUid*, as described above. Foreign domain authority 14 receiving this dynamic user identifier is unable to interpret it. However, it must know the user's home domain, domain 20 in the present case, in order to route or transmit the encrypted data to the correct (home) domain via gateway 30.

20

Gateway 30 - or any other gateway or relais station in the route - also is just able to interpret the user's correct home domain, but cannot read or interpret the dynamic user identifier *SUid*. In the present case, gateway 30 transmits the received encrypted user identifier to the user's home domain  
25 authority 24.

Domain authority 24, receiving the dynamic user identifier of its domiciled travelling user U has pre-computed up-to-date tables which list for the dynamic user identifiers for all all ist users, valid in the present time interval  
30  $\delta_x$ . Thus, by a fast and easy table look-up, domain authority can check whether the received dynamic user identifier is valid and to which user it belongs. This is described in some more detail in connection with Fig. 4. Domain authority 24 may then return an appropriate message to terminal 12

1 (from where the user desired service) and/or go through the authentication process.

As depicted in Fig. 4, when receiving a dynamic user identifier  $SUid$ , home domain authority 24 selects the appropriate alias table 42, say  $TB_2$ , from a series 41 of pre-computed tables  $TB_1$  through  $TB_n$  according to the current time interval  $\delta_x$ . It then searches the selected table using the supplied  $SUid$  value and identifies the serial number (or some other ID) of the smartcard or user workstation that computed  $SUid$ . The card serial number uniquely identifies the user. Once this identification is done, an appropriate message can be generated at domain authority 24.

Fig. 5 finally shows an example how the user's input can be processed in the input terminal 12 in the foreign domain. User U inputs his user ID or identifier  $A_U$ , his password  $PW_U$ , and, optionally, the current time  $T_U$ , rounded to the nearest time interval  $\delta_U$  into workstation or terminal 12 in the foreign domain. Processing means 51, including an encryptor 52, encrypts the user's inputs, i.e.  $i_1$  through  $i_3$ , which correspond to  $PW_U$ ,  $A_U$ , and  $T_U$ , as shown in the figure. Here, the concatenation of  $i_1$  and  $i_2$  is encrypted under DES, referred to above in (8), under the key  $i_3$ , determining  $SUid$ , which is sent to the user's home domain. There, authentication server 24 evaluates the received dynamic user identifier  $SUid$ .

The following is a stepwise description of the full process.

25

#### STEP 0

First, and preferably permanently, each (home domain) authentication authority  $AS_x$ , typically authentication server 24, computes the tables necessary for the process. This is done every so often, e.g., once a day. Thereby, a sequence of tables, e.g.  $TB_1, TB_2, TB_n$  is computed, where n is the number of  $\delta_x$  intervals in a day or other "long" time unit. For example, if  $\delta_x$  is set to one hour, authentication server 24 computes 24 tables every day.

1

Each table  $TB_i$  contains as many rows as there are users in the local domain. Each row consists of two columns:

- user name  $U$ , and
- 5 - the result of applying one-way function  $F(A_U, T_U, PW_U)$ , where  $PW_U$  is the password or PIN of user  $U$  and  $T_i = T_0 + \delta_X$ .

$T_0$  is the absolute time at the beginning of the computation start, i.e., if computation is done every day, then  $T_0$  is set to midnight.

10

This ends the first part of the process, i.e. the table computation. The following, second part concerns the identity resolution. To enable an easy understanding, it shall be described in several steps.

15

#### STEP 1

A user  $U$  travels to a foreign domain. At a terminal or workstation in this foreign domain, say terminal 12 of domain 10 in Fig. 3, he/she enters his/her user ID  $U_X$  or alias  $A_U$ , the  $\delta_X$  value, and his/her password (or PIN)  $PW_U$  into the workstation. From the input values, the workstation (software and/or hardware) computes the dynamic user identifier

20

$$SUid = F(A_U, T_U, PW_U),$$

where  $T_U$  is the local time on the workstation, rounded off to the nearest  $\delta_X$ , i.e. seconds, minutes or hours, depending on what units  $\delta_X$  is measured in. Note that it is not required for the workstation to have a clock; in that case, the user also enters the time  $T_U$ , e.g. by consulting his watch.

25

In addition, the user enters some authentication information into the workstation. It is not relevant to the present invention what this authentication information is.

30

1     **STEP 2**

The workstation sends the *SUId* value along with the authentication information to the user's home domain authority  $AS_X$ , e.g. to terminal (or workstation) 24 in domain 20. This may be done indirectly: workstation 12  
 5     can first forward the data to its own local authority  $AS_Y$ , e.g. workstation 14 of domain 10 which, in turn, then sends the data on to  $AS_X$ , here terminal or workstation 24.

**STEP 3**

10    When the data reaches  $AS_X$ , i.e. workstation 24, it first obtains its local time  $T_X$ . Then, it computes  

$$j = (T_X - T_0) / \delta_X$$
 using integer division, and  

$$k = (T_X - T_0) \% \delta_X$$
 wherein % is the modulus operator.

15    **STEP 4**

Next,  $AS_X$ , i.e. workstation 24, searches the table  $TB_j$  (pre-computed in Step 0), using *SUId* as the search value.

**STEP 4a**

20    If the search is successful, the table entry points to user U.

**STEP 4b**

If the search is unsuccessful, domain authority  $AS_X$ , i.e. workstation 24, may (depending on the value of k) search either  $TB_{j-1}$  or  $TB_{j+1}$ .  
 25

**STEP 5**

Once user U is identified, domain authority  $AS_X$ , i.e. workstation 24, verifies the authentication information that arrived along with a *SUId*, as known in the art. Again, details of this process are not relevant to the present  
 30    invention.

## 1 STEP 6

When domain authority  $AS_x$ , i.e. workstation 24, is satisfied that *SUID* corresponds to a valid user U and the accompanying authentication information is correct, it responds to the remote domain authority  $AS_y$ , here  
5 server 14 in domain 10, and communicates that *SUID* is a legitimate user who is authorized to obtain service.

Obviously, the above-described process does not use a smartcard. If an "Intelligent" card like smartcard 1 is to be used, the only change would be in  
10 Step 1. Instead of entering the info into the workstation, the user would simply read out the value displayed on the smartcard in its user ID mode and enter it into workstation 12. Alternatively, this value can be machine-read by workstation 12. This value is the *SUID* already computed by smartcard 1 in the same way as the workstation does it in Step 1 above.

15

To summarize, at the end of Step 6, domain authority  $AS_y$ , here workstation 12, can be assured that user U is a legitimate user while, at the same time, the domain authority does not and cannot discover the user's identity. In fact, domain authority  $AS_y$  only knows *SUID* which is nothing but a  
20 short-term alias. The correspondence between *SUID* and  $U_x$  is known only to the user U and his/her home domain authority  $AS_x$ .

There are obviously many variations of this invention imaginable, ranging from wireless, e.g. radio or infrared, transmission to multiplexing when  
25 serving several users simultaneously. In a wireless domain, a single server could be used as transceiver and domain authority simultaneously. Synchronization can e.g. be achieved by radio-controlled clocks or other synchronization devices. Smartcards could be carrying any meaningful computing power in order to make the terminals as robust as possible. All  
30 these variations could still be using the essential principles of this invention as defined in the appended claims.

1

## CLAIMS

1. A method for secure identification of a mobile user  $U$  in a communication system with a plurality of distributed users grouped to domains or subsets  $D_X, D_Y$  within the system, each said user having an identifier  $A_U$  and a password or other secret authenticator  $PW_U$ , said identifier and said password being stored in said user's home domain  $D_U$ , said method including a synchronization indication, preferably applying a time interval indication  $T_U$ , synchronizing said user's  $U$  input in a foreign domain  $D_Y$  with his/her home domain  $D_U$ ,

comprising the steps of:

- encrypting under a secret function, particularly a one-way function, at least one of the group consisting of said identifier  $A_U$ , said time interval or other synchronization indication  $T_U$ , and said user's password  $PW_U$  or other secret authenticator, and building an encrypted message,
- indicating to said foreign domain  $D_Y$ , from which said user  $U$  intends to communicate, said user's home domain  $D_U$ ,
- transmitting said encrypted message to said user's home domain  $D_U$ ,
- evaluating in said user's home domain  $D_U$  said encrypted message and determining the true identity of said user.

2. The identification method of claim 1. with distributed workstations and/or terminals (11-14, 21-24) grouped to domains or subsets  $D_X, D_Y$  (10, 20) within the system, wherein the encryption step is carried out in the foreign domain  $D_Y$  and the encrypted message transmitted to said user's home domain  $D_U$  for the evaluation.



- 1     3. The identification method of claim 1, using "intelligent" portable input means, preferably smartcards (1), with built-in computing power, wherein  
the encryption is carried out in said portable input means and the  
5     encrypted message transmitted to said user's home domain  $D_U$  for the evaluation.
4. The identification method of claim 3, wherein  
at least part of the entry into the foreign domain  $D_Y$  is done from the  
10     portable input means, preferably by machine-reading the latter.
5. The identification method of any of the claims 1 through 3, wherein
- if the determining step is successful, an approval message from the home domain  $D_U$  is transmitted, in particular to the foreign  
15     domain  $D_Y$ ,
  - if the determining step is unsuccessful, an appropriate disapproval is indicated.
6. The identification method of claim 1, wherein
- 20     — the secret function is a one-way function  
 $SUid = F(A_U, T_U, PW_U)$   
encrypting the identifier  $A_U$ , the time interval indication  $T_U$  or other synchronization indication, and the user's password  $PW_U$  or other secret authenticator, and/or  
25     — the identifier  $A_U$  is an alias or secondary identifier of user U.
7. The identification method of any preceding claim, wherein  
in the home domain  $D_U$ , prior to a respective time interval  $\delta_U$  or other  
synchronization interval indication, one or more potential encrypted  
30     messages for a future time interval are pre-computed and stored in a reference/translation table (42).

- 1     8. The identification method of claim 7, wherein  
the reference/translation table (42) in the home domain  $D_U$  is  
established selectively, in particular only for selected mobile users  
known to be moving.
- 5     9. The identification method of claim 1, wherein  
for each domain  $D_X$ , a domain-wide time interval  $\delta_X$  is selected, said  
selected time interval being one or more hours or a day.
- 10    10. The identification method of claim 1, wherein  
the synchronization means includes identically seeded random-number  
generators and/or secret sequence numbers.
- 15    11. A portable input means, in particular a smartcard (1), adapted for use in  
a communication system according to any of the claims 1 - 10, having a  
secret key unique for each input means and a clock, further comprising  
means for switching said input means between an identification mode  
and a user ID mode in which it displays the encrypted message.
- 20    12. The input means of claim 11, wherein  
switching said input means is done by a manual mode switch (4) for  
manually switching said input means between its modes and/or an  
automatic mode switch for automatically switching said input means  
time-dependant between its modes.
- 25    13. A system for secure identification of a mobile user in a communication  
network including a plurality of distributed workstations or terminals  
(11-14, 21-24) grouped to domains or subsets  $D_X, D_Y$  (10, 20) within said  
network, said user having an identifier  $A_U$  and a secret authenticator  
30     $PW_U$ ,  
— means for encrypting (Fig. 5) under a secret function, particularly a  
one-way function, at least one of the group consisting of said  
identifier  $A_U$ , a synchronization indicator  $T_U$ , and said user's

- 1 authenticator  $PW_U$ , for building a first message, and indicating said  
user's home domain  $D_U$ .
- means for transmitting (16, 26, 30) said first message to said user's  
home domain  $D_U$ .
- 5 — means for receiving (Fig. 4) in said user's home domain  $D_U$  (20)  
said first message, and determining the true identity of said user  
U.
14. The identification system of claim 13, wherein
- 10 message control and handling within the foreign domain  $D_Y$  (10) and/or  
within the home domain  $D_U$  (20) is done within and by a domain  
authority or an identification server  $AS_Y$  (14) or  $AS_U$  (24), respectively.
15. The identification system of claim 13, including
- 15 in a domain authority  $AS_U$  (24), means (41) for storing a plurality of the  
translation tables (42).

20

25

30

1/3

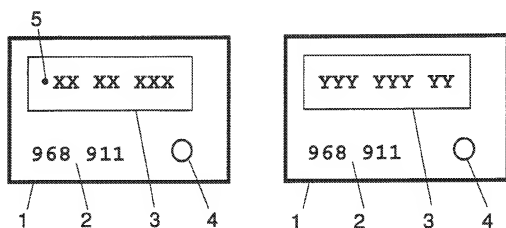


Fig.1

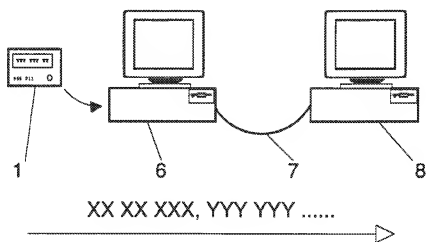


Fig.2

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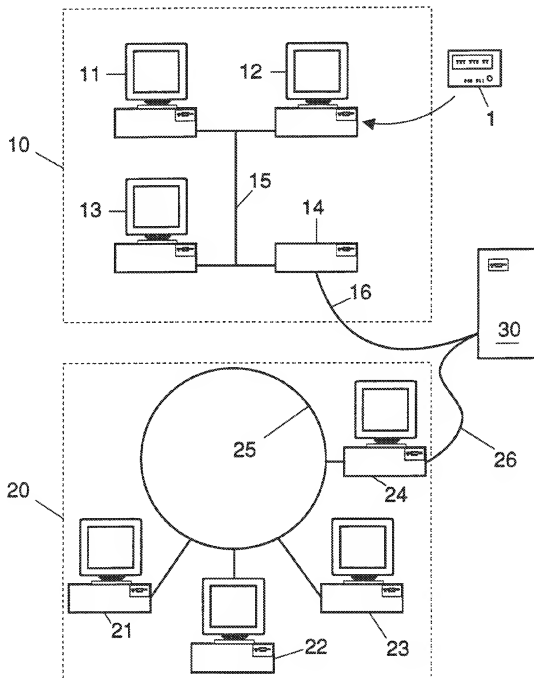


Fig.3

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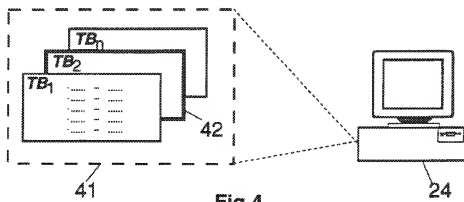


Fig.4

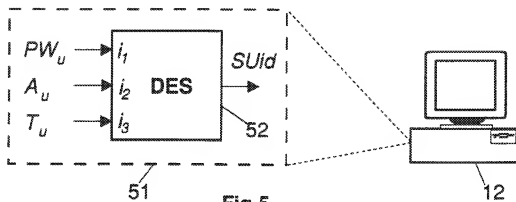


Fig.5

## INTERNATIONAL SEARCH REPORT

International Application No.  
PC./EP 94/03542

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 H04L9/32 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04L H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category: Citation of document, with indication, where appropriate, of the relevant passages

Relevant to claim No.

A IEEE NETWORK: THE MAGAZINE OF COMPUTER COMMUNICATIONS, March 1994 - April 1994 NEW YORK US, pages 26-34, R.MOLVA ET AL. 'AUTHENTICATION OF MOBILE USERS' cited in the application see page 26, left column, line 1 - line 20 see page 30, left column, line 14 - line 18 see page 32, right column, line 32 - page 33, left column, line 31  
---  
-/-

1, 13

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

## \* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

30 August 1995

Date of mailing of the international search report

04.10.95

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Authorized officer

Lydon, M

## INTERNATIONAL SEARCH REPORT

Inter- national Application No  
PC., EP 94/03542

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>EP-A-0 532 227 (AMERICAN TELEPHONE AND TELEGRAPH COMPANY) 17 March 1993  see page 3, column 3, line 30 - line 55  see page 3, column 4, line 53 - page 4, column 5, line 39  see page 4, column 6, line 10 - line 17  see page 5, column 7, line 6 - column 8, line 8  see page 5, column 8, line 38 - page 6, column 9, line 31  see page 8, column 13, line 50 - column 14, line 4  see figures 1,2,11</p>	1,13
A	<p>-----  PROCEEDINGS OF GLOBECOM'93 - IEEE GLOBAL TELECOMMUNICATIONS CONFERENCE HOUSTON(US),  29 November 1993 - 2 December 1993  NEW YORK (US),  pages 550-554,  H.-Y.LIN &amp; L.HARN 'AUTHENTICATION IN WIRELESS COMMUNICATIONS'  see page 551, left column, line 15 - line 45  see page 551, right column, line 3 - page 552, left column, line 23  see page 552, left column, line 41 - page 553, left column, line 12  see figures 1-3</p>	1,13
X	<p>-----  COMPUTERS &amp; SECURITY INTERNATIONAL JOURNAL DEVOTED TO THE STUDY OF TECHNICAL AND FINANCIAL ASPECTS OF COMPUTER SECURITY., vol. 6, no. 1, February 1987 AMSTERDAM NL,  pages 10-11,  J.H.HIGHLAND 'TECHNOLOGY WATCH - PERSONAL AUTHENTICATION DEVICES'  see page 11, left column, line 13 - line 26  see figure 3</p>	11,12
A	<p>-----  PROCEEDINGS OF 1993 IEEE COMPUTER SOCIETY SYMPOSIUM ON RESEARCH IN SECURITY AND PRIVACY OAKLAND (US)  24-26 MAY 1993  NEW YORK (US),  pages 56-65,  R.MOLVA &amp; G.TSUDIK 'AUTHENTICATION METHOD WITH IMPERSONAL TOKEN CARDS'  cited in the application  see page 59, paragraph 5.1  see figure 1</p>	12

3



## INTERNATIONAL SEARCH REPORT

national application No.

PCT/EP 94/03542

**Box I** Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box II** Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. Claims 1-10, 13-15: A method and system for secure identification of a mobile user in a communication network.
  2. Claims 11-12: A portable input means with means for switching between an authentication mode and a user ID mode.
1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
  2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☒ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. Application No

PCT/EP 94/03542

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-532227	17-03-93	US-A- JP-A-	20-04-93 08-07-94
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